The Influence of Incentive and Punishment upon Reaction-Time

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THE INFLUENCE OF INCENTIVE AND PUNISHMENT UPON REACTION-TIME

BY

ALBERT M. JOHANSON, Ph.D.

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CONTENTS

INTRODUCTION

Many of the earlier investigators of reaction-time conducted experiments in which such factors as the personal equation, the physiological time of conduction, the kind of stimulus, its intensity, duration and so forth, the optimal interval between the foresignal and the stimulus were the matters of most concern. A later tendency seemed to be towards a consideration of the internal conditions attendant upon the reaction. Such factors as the direction of the attention, practice and fatigue, and the reaction movement were seriously studied. More recently attention was directed to the introspective analyses of the reaction. By this method such problems as those of the reaction movement and expectant attention in reactions were investigated.

The present investigation was conducted with a view towards considering the external conditions and their results upon the reaction. The effect upon the time of the reaction was studied by varying these conditions and noting the variations in the results. A comparison with the conditions recognized as "standard" was thus possible. Little if anything has as yet been done along these lines of varying the accompanying factors, so the history of previous works will perforce be brief.

This investigation may be divided into two parts. The first is a study of the influence of incentive upon the normal reaction to sound. The second part comprises a consideration of the influence of punishment upon the normal reaction to sound.

The writer desires to express his great obligations to Professor Woodworth, Professor Hollingworth, and Professor Poffenberger, for their kind interest and guidance, and to Mrs. Helen H. Wheeler, Mr. Joseph L. Holmes and Mr. Howard K. Nixon, of the Department of Psychology, for their generous assistance as subjects in this experiment.

Chapter I

FACILITATING FACTORS

Though not a factor in the investigation, suggestion is so closely akin to incentive, as it is used here, that it seemed it would be of interest and would give a setting to the problem to have it included. Some of the investigations, though under the name of suggestion, are not strictly confined to suggestion, but include also an element of incentive which is of primary interest and ought, therefore, to be mentioned. Furthermore, the effects of incentive are also the effects in some forms of the suggestion experiments, and as such are worthy of review. But, since the question of suggestion is only subsidiary to our real problem, it will not be necessary to give a complete account of its rather extensive literature. Only the more noteworthy and those bordering on incentive will be mentioned.

1. *History of the Inquiry into Suggestion.*

The field of suggestion is replete with experimental investigations of the bearing of suggestion upon various types of work and reactions to stimuli as met with under everyday conditions; upon the great range of individual differences in responding to suggestion, but as yet little has been accomplished in the way of investigating the part played by suggestion under rigidly standardized conditions when measuring the time of a response to a stimulus.

One of the earliest to report his work on suggestion was Binet[1]. He reports an experiment on children in which the subject was to draw a line equal in length to a line shown them. In these reproductions there was a marked tendency to draw the line too short. Seventy-eight out of eighty-six made it less than fifty millimeters, the length of the original. The reproductions varied in length from twenty-eight to sixty millimeters. They were then informed that a longer line would be shown, which they were to reproduce in like manner. The line which they were shown, however, was actually shorter, measuring only forty millimeters. Only nine of the eighty-six drew the second line shorter than the first, and of these only one drew it ten millimeters shorter. They were then told that a third line a little shorter than the second would be shown them, whereupon the original line of fifty millimeters was presented again. This sug-

[1] Binet, "La Suggestibilite", L'annee Psychol. V., 99, 1899.

gestion was less efficacious than the first; only seventy of the eighty-six yielding to it. The amount of error was likewise reduced.

Pearce[2] tested the influence of a suggestive stimulus upon the extent of eye movements as indicated by visual localization. He noted that with a single peripheral stimulus the error toward the fixation point increased with the distance of the peripheral stimulus from that point. With the suggestion stimulus there was at first a tendency to resist the suggestion, but this diminished as the suggestion was repeated. The resistance was most vigorous when the suggestion was contrary to the normal error; but ultimately the suggestion opposed to the normal tendency was most effective. Contrary to later investigators, Pearce found that the same person showed the highest degree of suggestibility in all tests whether with visual, auditory or tactual stimuli.

Smith and Sowton[3], though not the next in point of time to report their investigations, are mentioned at this time as they employed the same method as their predecessors. They have investigated the effect of what they called "successive contrast." A line varying from two to twenty centimeters was shown and immediately afterward a standard line of ten centimeters was exposed. The length of the standard was to be marked off on a line already drawn on a sheet of paper. In all cases, both with and without the modifiers, the standard was underestimated, but for one subject modifiers of two to ten centimeters produced an average increase of 1.2 mm., in the estimation, while modifiers of ten to twenty centimeters caused an average decrease of 0.9 mm. That is, the shorter lines acted as a positive suggestion, the longer ones as negative.

The experiments thus far reported were made with but slight differences in the method of investigation. In the earlier experiments the observer was given no instructions to resist any influence by suggestion. With Brand[4] a radically new method was adopted. The subjects were aware of the purpose of the experiment and while the idea of suggestion was to be given place in the mind the observers were warned against any voluntary response to it. Furthermore, the reactions depended not alone upon visual perception, but primarily upon the power to reproduce. The purpose of his experiment, as he states it, was, "to find out how far and in what direction the visual estimation of a linear magnitude could be affected by suggestion of certain possible errors in such estimation, the subject knowing that

[2] Pearce, "Normal Motor Suggestibility", Psychol. Rev. IX., 1902, 348.

[3] Smith and Sowton, "Observations on Spatial Contrast and Confluence in Visual Perception", Brit. J. of Psych. II., 196-219.

[4] Brand, "The Effect of Verbal Suggestion upon the Estimation of Linear Magnitudes", Psych. Rev. 12, 1905, 41-49.

the suggestions were purely arbitrary, i.e., that they had no reference to any foreseen tendency to err in any direction." He tested the effect of printed mottoes on the reproduction of horizontal lines. These lines varied from twelve to thirty-four centimeters in length and were represented by the interval between two pegs situated at a distance of 120 cm. from the eyes of the observer. The observer reproduced this interval by spacing two similar pegs on a ledge 40 cm. from his eyes. The eight different suggestions used were printed upon white cardboard in letters 1.2 cm. high. The experimenter presented them to the subject by displaying the cardboard for a moment. After the suggestion had been presented, the experimenter displayed two small objects upon his frame and then called upon the subject to respond by setting up his two similar objects upon his own frame at a distance from each other approximating as nearly as possible that of the original objects. It does not seem possible to make very clear-cut deductions from his results, with the possible exception that the two brief suggestions, "make short" and "make long" tend more than the other suggestions to make the reproduced distance greater in magnitude, and the two suggestions, "Don't make too long" and "Don't make too short," tend to a less degree to have the same effect.

Bell[5] conducted an experiment in which two types of suggestion were used,—auditory and visual. For the former suggestion "high" and "low" were used, being spoken by the experimenter just before the presentation of the object to be reacted upon. For the visual suggestion a diamond-shaped figure twenty centimeters long and four centimeters wide was shown to the subject. The instructions were to reproduce the triangles of different shapes and heights as they were presented. Three were reproduced with "high" suggestions, and three with "low" suggestions, and three without any suggestions.

Bell concludes that in general the suggestions do affect the reproduction of the triangles; that the auditory suggestion is more effective than the visual; and that in the auditory set the "low" suggestion is more effective than the "high." Throughout the experiment susceptibility to "low" suggestion was more general and more uniform than to the "high" suggestion. But the weakness of his experiment lies in the small number of observations made for each subject with each type of suggestion. Only three observations were taken for each type. Averages drawn from so few cases are of very doubtful reliability.

[5] Bell, "The Effects of Suggestion upon the Reproduction of Triangles and of Point Distances", Amer. J. of Psych. XIX., 1908, 504.

Strong[6] made a more creditable investigation. His experiment was to give the subject a suggestion and have him respond each time with his maximum grip. Collin's elliptical form dynamometer was used and from it an expression in kilograms was obtained of his muscular activity. In all, seven suggestions were employed which may be classified as follows:

Auditory Suggestion:
Positive, "Now you can make it stronger than usual."
Negative, "Now you can't make it as strong as usual."

Visual Suggestion:
Positive: A plus sign on a card was presented.
Negative: A minus sign on a card was presented.

At the beginning of the experiment each subject was informed that the plus sign was meant to suggest to him that he could make his grip stronger than usual and the minus sign was meant to suggest the contrary. These signs were consequently visual suggestions depending on previous vocal instruction.

Auto-suggestion:
Here the experimenter announced, "Now you can make your own suggestion." The subject understood by this that he was at liberty to suggest to himself either the positive or negative suggestion and to designate his choice to the experimenter by audibly announcing it. In this case as soon as the subject had announced his suggestion the dynamometer was handed to him and the experiment continued as usual.

Neutral Suggestion:
This consisted of an announcement, "Now neutral," and was intended to act merely as a check and guide to what would be the exertion if no suggestion of any sort were given.

Strong concludes that suggestion as a whole heightens the maxima. Negative suggestions tend more than the positive to heighten the maxima, but with some subjects the positive suggestions as a general rule are superior to negative suggestions in this respect. Auto-suggestions tend most strongly of all types of suggestion to heighten the maxima. For some of his subjects, visual was superior to auditory suggestion.

Jones[7] reported an experiment which consisted in having the subject

[6] Strong, "The Effect of Various Types of Suggestion upon Muscular Activity", Psych. Rev. 17, 1910, 279-293.

[7] Jones, G. M., "Experiment on Distance as Influenced by Suggestion of Ability and Inability", Psych. Rev., 1910, 17, 269-78.

place two pegs the same distance apart as two which the experimenter had exposed to his view shortly before. There were six varieties of suggestion employed and response was also made to one signal where no suggestion was offered. The visual suggestion was made by means of printed mottoes, such as, "You are now able," and "You are now unable." The vocal was made by the experimenter to the observer in the same words, and the "auto," was made by the subject to himself in the words, "I am now able," or "I am now unable."

In view of the fact that the judgments made under suggestion, whether affirmative or negative, show so frequently an increase in variability and error beyond that in the judgments made without suggestion, it may be inferred that suggestion does in itself and apart from the actual contents of the suggestion, effect some change in the reproduction of distance.

It is also significant that the suggestion acts to a considerable degree in a direction corresponding to the actual contents of the suggestion given. That is, the error and variability under suggestion of ability were almost always less than when suggestion of inability were made.

The conclusion that Jones draws is that negative suggestions (suggestion of inability) were about twice as effective as were the positive or suggestions of ability. Moreover, the auditory negative suggestions were most effective of all.

Powelson and Washburn[8] in 1913 reported a study to determine the effect of verbal suggestion on judgments, of the affective value of colors. All of the ninety Bradley colored papers were used and the subjects were instructed to judge the pleasantness or unpleasantness of the color. The middle eighteen colors of the series were presented with an accompanying verbal suggestion as to their affective value. In the first sitting for half of the observers, the verbal suggestions accompanying this part of the series were suggestions of unpleasantness, and in the second sitting the suggestions were of pleasantness. The suggestion took the form of favorable or unfavorable adjectives pronounced by the experimenter as the color was shown. For instance, "faded", "delicate", "warm", "crude", were the terms used. Of thirty-five observers, twenty-five gave results indicating a positive effect of suggestion in altering the judgments of affective value. The investigators conclude, therefore, "that direct verbal suggestion regarding the pleasantness or unpleasantness of a color has a fairly decided positive effect upon the judgments of observers of the type and under the conditions found in our investigation."

[8] Powelson and Washburn, "The Effect of Verbal Suggestion on Judgment of the Affective Value of Colors", Am. J. of Psych., 1913, 24, 267-9.

Poffenberger[9] has reported in a Master's thesis some differences in suggestibility found by using an electric shock as the stimulus in a reaction experiment. What he did was to have the subject react as soon as he felt the electricity in his reaction key. The shock stimulus was strong at first, then gradually reduced to a minimal point. The reaction was made just the same. In this part of the experiment the sight of the operator's key being thrown was the suggestion factor.

A second group was tested under slightly varied conditions. The suggestion this time was the sound of a falling screen and the presence of a 4 c.p. light. The lamp was arranged in connection with the falling screen so that the light flashed on one one-hundredth of a second before the stimulus was felt in the key. The results obtained show the suggestion time to be slightly quicker or shorter than the normal reaction-time. He concludes also that there is a wide range of individual differences in suggestion to an electric shock. The most suggestible subject had the shortest suggestion time. And finally, women are more suggestible than men, having a greater proportion of successful suggestion reactions and shorter suggestion-time.

The experiments and investigations thus far reported appear to be the more important ones on suggestion and the ones most closely allied to the present investigation. But digressing a few steps, another field may be entered which, though closely related to suggestion, has a direct bearing upon the problem under discussion.

2. *History of the Inquiry into Incentive.*

In the preceding section experimental studies directly involving suggestion were reviewed. The results of these several investigations may be generalized in some such statement as: suggestion tends in almost every case to assist in the performance of the task by materially reducing the time of the performance, or by increasing the amount of work accomplished in a stated period of time, but with some individual differences. In this next section, the aim will be to show how other factors, aside from pure suggestion, may affect the performing of a task. This group or set of conditions has been quite generally designated by the term "dynamogenic factors," or again as "facilitating factors."

James[1], writing of the principle of dynamogeny, says, "Every sensorial stimulus not only sends a special discharge into particular

[9] Poffenberger, "Individual Differences in Suggestibility with the Use of an Electric Shock", Master's Thesis, 1910.

[1] James, "Principles of Psychology", I., 90ff., 1890.

muscles dependent on the special nature of the stimulus in question, but it innervates the muscles generally."

Féré[2] has given experimental proof of this. The strength of contraction of the subject's hand was measured by a dynamometer. The maximum strength under simple experimental conditions remains the same from day to day. But, when a sensorial stimulation was given simultaneously with the pressure on the dynamometer, a greater force of contraction was produced than when the sensorial stimulation was absent. The effects of sound and musical notes on the muscular effort were also studied. He found that increasing the loudness and pitch caused corresponding increases of muscular effort. The contraction power was decreased by sad notes, but increased with gay notes. The increase of effort varied with the color of the light used. Red was found to be the most exciting color. Tastes and odors were likewise found to have a dynamogenic effect. Cutaneous sensations—heat, cold and so forth—had a facilitating influence. Féré reported also that more work could be done with the eyes open than closed. In working a Mosso ergograph he found that moving the legs and counting aloud reenforced the fingers in their contractions.

Arps[3] undertook to investigate to what extent awareness and partial awareness of results were factors conditioning efficiency. The question to which he experimentally found an answer was whether a condition of relatively complete awareness of results was more or less favorable to efficiency than was a condition of partial awareness. To what extent did knowledge of the results further efficiency; or to what extent did a lack of knowledge curtail efficiency, were other points of interest in his experiment. Further, was a response in which a knowledge of the results constituted the essential features, more or less efficient, than a response when such knowledge was relatively lacking? The work was done with the ergograph and continued to exhaustion. His conclusions were that the organism functions more effectively when the ergographic tracings were immediately present stimuli. Both the absolute amount of work and the rate of work done under conditions of knowledge of the results exceed that done under conditions of ignorance of results.

Whipple[4], in determining the influence of forced respiration found that it had a reenforcing power on most activities. The tests he used were both physical and mental, including the dynamometer grip,

[2] Féré, "Sensation and Movement", 26-50.

[3] Arps, G. F., "Work with Knowledge of Results versus Work without Knowledge of Results", Psychol. Monog., 1920, 28.

[4] Whipple, "The Influence of Forced Respiration on Psychical and Physical Activity", Am. J. of Psych., 1897, 9, 560.

adding of digits, card sorting, simple reaction to sound, memory span, and several others. He concludes that there is an improvement of the muscular mechanism at the expense of mechanisms of control and of the higher functions generally.

Judd[5] has performed an investigation which has an aspect similar to a part of the present experiment. His work was on "Practice without Knowledge of the Results," from which the conclusion is drawn that greater efficiency results when the observer is aware of the conditions underlying the procedure of the experiment. The several series of reactions in the present work provide an analogous case to that of Judd's.

In his experiment, however, the subject was shown a line drawn so as to slope upward or downward at varying degrees. The subject was to continue the line, doing it without seeing what he was doing. "When a given line appeared the subject was required to place a pencil on the opposite, or unseen side of the screen, in what he regarded as the exact continuation of the line." The screen prevented him from seeing how accurately he had located the point.

The striking fact, which appears in the results of these experiments, is that practice brings little if any change. The first and last day differ from each other about as did the first and second. There is no motive for improvement. The subject cannot see his results and cannot, therefore, judge of their success or failure. Under the conditions which obtained in his experiment, the incentive for improvement was entirely suppressed largely because the subject did not know what was occurring.

Some more recent investigations have been conducted by Chapman and Feder[6]. These men wished to determine to what extent an increased interest stimulated an increased effort. The general method of the experiment was to give extended practice in three tests to two similar groups of children, one group working under normal conditions while the other was motivated by external incentives. The results showed that the incentive exerted a considerable effect on the amount of the product. The incentives used were the individual's results of the previous day published in some conspicuous place.

Another experiment carried out with children as subjects was performed by Bronner[7]. She determined the effect of attitude upon the performance of tests by testing children under different conditions

[5] Judd, "Practice without Knowledge of Results", Psych. Rev. Monog. Supp. II., 1905.

[6] Chapman and Feder, "The Effect of External Incentives on Improvement", J. of Educ. Psych., 1917, 8, 469-74.

[7] Bronner, A. F., "Attitude as it Affects Performance of Tests", Psych. Rev., 1916, 23, 303.

or attitudes towards the tests. By appeals and by reasoning with them and by informing them as to the meaning and value of a good score, many cases with high scores were obtained. Summarizing the viewpoint of the report, she states in part that, "mental attitude has been discussed so far as a factor in the learning process. Thorndike has enumerated the laws of learning. He says, 'Purposive behavior is the most important case of the influence of attitude.' Again, 'It is a general law of behavior that the response to any external situation is dependent upon the condition of the man as well as upon the nature of the situation.' Ruger states that the attitude of confidence was a great aid in the successful solving of puzzles."

Some interesting experiments have been worked out recently by Wright[8] to determine the effect of incentives upon one's work. These experiments, consisting of three series, were conducted for the purpose of comparing quantitatively the amounts of work that were accomplished by the subject working under two different mental attitudes. One, that of mere doing because the subject was told to work as hard as he could and as long as he could with no idea of securing any specified result. The other, that of doing a prescribed task as long as strength endured. With the first task all incentive, as, the watching of the instrument or the keeping track of his progress by counting the strokes was denied the subject; whereas under the second condition the subject was not only permitted to watch his strokes, but was also stimulated to action part of the time by his being requested to count his strokes.

To furnish a definite motive for the second class of responses, blocks were inserted under the carriage of the ergograph. The subject was required to push merely to the block and to exert himself to see how many times he could reach it.

The results show a gain for all the subjects in the work performed under the conditions of the second class, that is, with incentives. Wright interprets his results as follows: "The difference in the mental attitudes of the subject under the different conditions imposed upon him in the performance of his tasks affected in no uncertain manner the results accomplished by him; or, as a more general deduction, in seeking the greatest results in the amounts of work to be secured by bodily exertion, the mental attitude of the subject towards his work should be taken into consideration." It was also shown that when working with the incentive there was less fatigue though more work was accomplished.

[8] Wright, W. R., "Some Effects of Incentives on Work and Fatigue", Psychol. Rev., 13, 1906, 23-34.

In another series, a somewhat different incentive was used. A line was drawn on the recording smoked sheet not quite beyond the reach of the subject. In working with this incentive the subject was instructed to watch his work, count his strokes, put forth his utmost effort with each stroke, and, to endeavor to reach the line as often as possible. In a final series the incentive (a line on the smoked sheet) was completely beyond the reach of the subject.

The conclusions arrived at from this experiment are, that the subject accomplished more work when working under the mental stimulus of having a set task to be performed, than he did when working without a definite aim. In the third part, where the line was beyond reach, a known impossibility to accomplish the required conditions tended to decrease the subject's total results. The feeling of fatigue accompanying work was not so great when the subject was working under the direct stimulus of a definite aim notwithstanding the fact that he had at the time produced an increase in his amount of work.

Cleghorn[9] conducted an experiment to show how voluntary muscular contractions could be reinforced. The subject contracted against a weight of two kilogrammes using the ergograph apparatus. A light flashed into the eye, a sudden sound, and induction shocks applied to the skin were the stimuli used. It was found that a sensory stimulus applied just as the muscle was beginning to contract, caused an increase in the height of the contraction.

Many experiments have been performed in the case of the various natural reflexes showing the facilitating effect. Lombard[10], experimenting upon the patellar reflex, found that when other sensations came in simultaneously with the tap, the jerk was increased. For example, clinching the teeth just before the patella was struck reenforced the knee-jerk. He also studied the effects of irritation of the skin, of exciting the attention, of exciting mental work, of music, and found under these conditions a reenforcing effect.

Yerkes[11], in testing the effect of auditory on visual and tactual stimuli in frogs, found that if the auditory stimulus preceded another stimulus by various time-intervals, it had an alternating reenforcing and inhibitory effect. A reflex movement of the leg was chosen as an indication of the action of the stimuli and the influence of sounds was observed. The auditory stimulus was either the sound of a quick

[9] Cleghorn, A., "Reinforcement of Voluntary Muscular Contractions", Am. J. of Psysiol., 1898, I., 336-45.

[10] Lombard, "Reenforcement of Knee-Jerk", Am. J. of Psychol., 1887, I., 18.

[11] Yerkes, "The Sense of Hearing in Frogs", J. of Comp. Neurol. and Psychol., 15, 4, 1905.

hammer blow or the ringing of an electric bell for a certain interval. The tactual stimulus was given by a rubber point. Reactions to the stimuli were taken in pairs regularly at half minute intervals, first a reaction to the tactual stimulus alone, then a reaction to the same intensity of touch when accompanied or preceded by an auditory stimulus. The influence of the sound is discovered by direct comparison of the tactual reaction of each pair with its corresponding auditory-tactual reaction. He concludes that when the tactual reaction is the greater, the sound has partially inhibited the reaction; when it is the smaller, that it has reinforced the reaction; when the two are equal, that it has been without influence. The tactual stimulus regularly causes a reflex movement of the leg. The sound, on the contrary, never causes the slightest movement.

Hofbauer[12], in a similar experiment on human subjects, arrived at the same conclusions. He found that firing a pistol caused a rise in the ergographic record.

Turley[13] tested the effect of a stimulus on its duplicate in a succeeding series of stimuli. Exactly determinable time-intervals between the stimulus and its duplicate were introduced. He concluded that, "(1) If a stimulus precedes at various time-intervals its duplicate in a series of stimuli, it will alternately inhibit and reenforce the perceiving of the duplicate stimulus. (2) Within four and one-half seconds there are at least three points each of maximum inhibition and maximum reenforcement." "(4) Up to 4.5 seconds, as the time-interval increases, the maximum inhibition generally decreases, while the maximum enhancement correspondingly increases."

Bliss[14] found that the reaction-times to sound heard in two ears were shorter than the reaction-times for the same sound heard in one ear. Poffenberger[15] found that the reaction-times to a light seen with the two eyes were less than the reaction-times to the same light seen with one eye. Todd[16] found that whenever another stimulus was added to a given stimulus the reaction-time was reduced. Or if a third stimulus was added to a pair of stimuli the reaction-time was reduced.

Competition is a strong dynamogenic agent. Experimental proof of this was obtained by Triplett[17], in a laboratory race. Two fishing

[12] Hofbauer, "Interferenz zwischen verschiedenen Impulsen im Centralnervensystem", Pflugers Archives, Bd., 68, 564, 1897.

[13] Turley, "Inhibition and Reenforcement", Harv. Psych. Stud., 2, 1906.

[14] Bliss, "Investigations in Reaction-time and Attention", Yale Studies, 1-4, 31, 1892-6.

[15] Poffenberger, "Reaction-time to Retinal Stimulation", Archives of Psychol., 25, 1912.

[16] Todd, "Reaction to Multiple Stimuli", Archives of Psychology, 25, 1912.

[17] Triplett, "The Dynamogenic Factors in Pacemaking and Competition", Am. J. of Psychol., 1897, 9, 507-33.

reels were used in the experiment. The subject, instructed to turn his reel at the highest possible rate of speed, worked at the side of a competitor who reeled at the same time with a similar instrument. From this simple experiment Triplett concluded as follows: "From the above facts regarding laboratory races we infer that the bodily presence of another contestant participating simultaneously in the race serves to liberate latent energy not ordinarily available. This inference is further justified by the difference in time between paced competition races and the paced races against time, amounting to an average of 5.15 seconds per mile up to 25 miles." "The sight of the movements of the pace makers or leading competitors, and the idea of higher speed, furnished by this or some other means are probably in themselves dynamogenic factors of some consequence."

Part of the dynamogenic effect of competition comes from the social element, and part from each performer's having a definite measure of his performance. Just as in the practice experiment, it has been found that presenting the records to the individual and allowing him to have them before him in the form of a curve, and urging him to compete against his own previous performance, causes the individual to accomplish more and progress faster than he otherwise would, so in this reaction experiment, the incentive of his previous record caused a greater speed to be developed.

Chapter II.

THE EXPERIMENT

In all of the foregoing reports of investigations, it has been noted how the factor of incentive helped to produce better results, either by a reduction in the time of the performance, or by an increase in the amount of work accomplished. It has also been noted that experiments with this purpose have been conducted over a very extended period, but no one up to the present time has used either a positive or a negative incentive with reaction-time in the manner in which it has been employed here.

This investigation will show how reaction-time can be reduced by accompanying factors so that a normal time, apparently as quick as the individual is able to respond, is brought much below the usual level of response. In the first part of the experiment an incentive was included to speed up the reaction process. The incentive was the time the subject had taken in his previous response to the stimulus, measured in sigma. The second part of the experiment included the series of reactions accompanied by a negative incentive or punishment. In this case the subject was given an electric shock for slow reactions. The results show a very decided improvement due to this unpleasant conditioning factor.

1. *The Apparatus.*

To record the reaction times, we were fortunate in being able to use the Hipp chronoscope modified and tested by Poffenberger and Morgan[1]. Their principal change was the replacing of the springs by a counterweight as devised by Dunlap[2]. The arrangement of the circuits was according to Dunlap's method. The University current (direct current), reduced through a rheostat so that the strength of the current was four volts, was the main source of supply. The various circuits were led off from the rheostat. One line led to the lower electromagnets of the chronoscope by way of the subject's reaction key. The ordinary telegraph key was used as a reaction key. From the chronoscope the circuit was continued to the upper contact post of the Wundt sound hammer, then through a mercury cup at

[1] Poffenberger and Morgan, "The Hipp Chronoscope: Its Use and Adjustment", J. of Exp. Psychol. I., 3, 1916, 185-199.

[2] Dunlap, K., "The Hipp Chronoscope without Armature Springs", Brit. J. of Psychol., 1912, 5, 1-7.

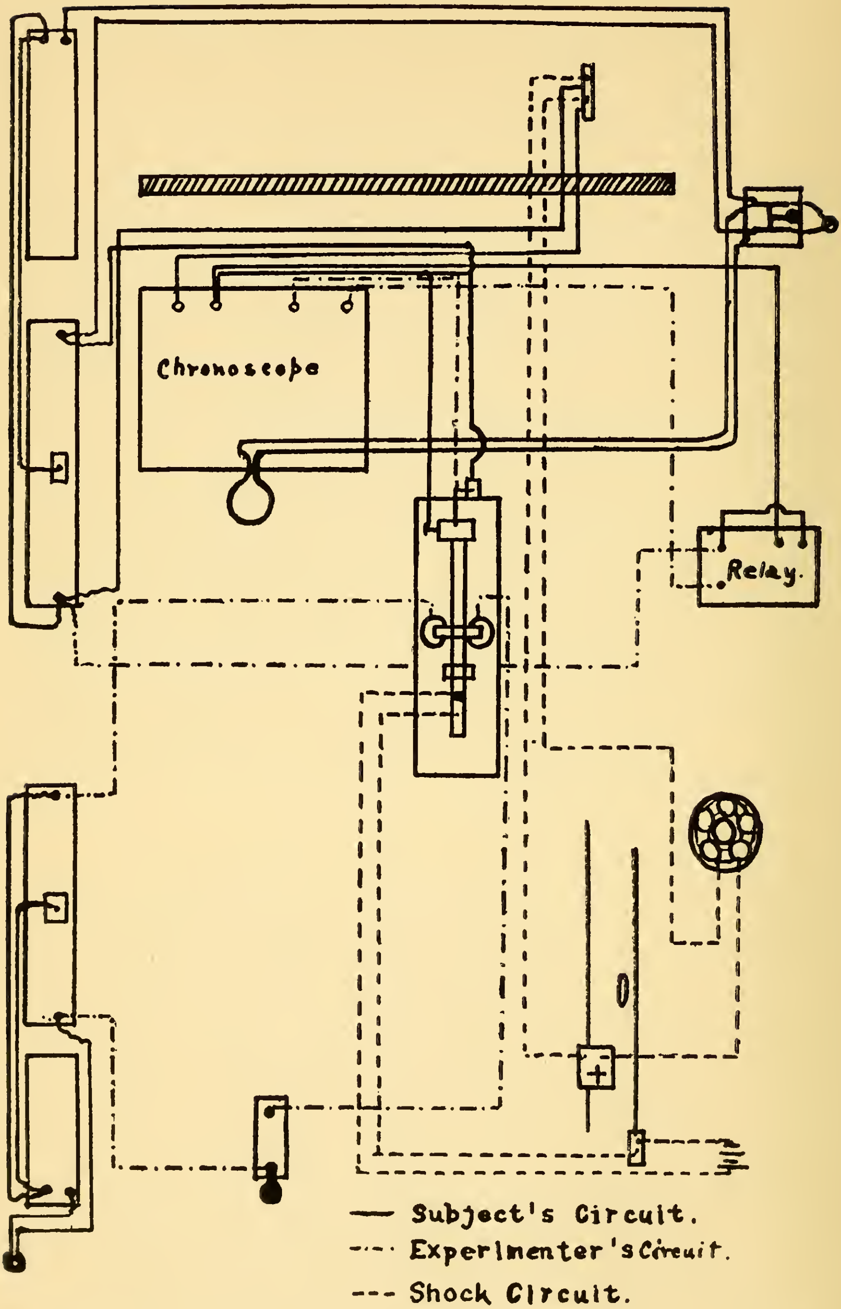

Fig. 1. Diagram of Apparatus

its base where the circuit split, one-half leading back to the chronoscope and completing what may be designated as the subject's circuit. The other lead from the mercury cup was taken to the electromagnets of the chronoscope, through a relay and back to the rheostat. By reference to Fig. 1 it will be apparent that by wiring in this manner it was impossible for premature reactions to be recorded unless the sound hammer had actually struck the base and completed the experimenter's circuit, under which condition a premature reaction would affect the reading of the chronoscope. Then to insure a sufficiently long make and break interval in the operator's circuit, a simple relay was included. The circuit from the upper electromagnets of the chronoscope was taken through the relay and back to the rheostat. Thus arranged, the key, which gave the sound stimulus and opened the circuit through the upper magnets of the chronoscope was made to open or close, as conditions warranted, the circuit through the electromagnets of the relay. The armature of the relay when released again made the circuit through the upper magnets. Thus this set of magnets was ready to draw the chronoscope armature up as soon as its release was effected from the lower pair of magnets.

From another source, a current reduced as before to four volts by being passed through a bank of lamps and a rheostat, was taken to the electromagnets of the sound hammer. In this line a simple switch was cut-in which served as the experimenter's control of the stimulus.

Another direct circuit was taken from the University current, passed through a bank of four 40 watt lamps arranged in parallel, to a trip-switch device located on a wooden bar. This switch was connected with the subject's key, wired and insulated so that the current passed through two small copper plates attached to the rubber knob of the telegraph key. By means of this circuit the inclusion of the electric shock was controlled. The trip-switch device used to throw the current on or off acted practically instantaneously.

A three cell battery circuit connected to an electromagnet magnetized it so that it held a pendulum at one end of its arc. In this circuit was placed a mercury cup acting as a make and break or more simply as a switch operating with the throw of the sound hammer arm. The break of the circuit was thus simultaneous with the giving of the stimulus. The small mercury cup was placed directly under the arm of the sound hammer with a wire leading to the electromagnet. The other wire in the same circuit, dipping into the mercury cup, was fastened to the arm of the hammer, but insulated from it. As the end

of the wire was lifted out of the mercury cup with the downward stroke of the hammer, the circuit was broken as the stimulus was given. Breaking the circuit demagnitized the electromagnet, thereby releasing the pendulum which in its swing tripped a small pin in the trip-switch mentioned above to throw the current into the plates on the subject's reaction key. The bar upon which the trip-switch was fastened was fully graduated with a time scale in sigma. The switch could be adjusted upon this scale whenever it was necessary to vary the length of the interval between the giving of the stimulus and the giving of the electric punishment.

The subject was entirely screened off from all the apparatus except his reaction key. There were absolutely no distracting sounds of any sort whereby the subject might be enabled to anticipate the stimulus. The only warning of a stimulus was the ready signal, which will be discussed later. Such sound as was made by the relay, the click of the armature against its magnets, was inaudible to the subject as it occurred simultaneously with the stronger sound stimulus. Any slight noise made by the experimenter in moving or throwing the switches was effectively concealed by the constant hum of the chronoscope mechanism.

By having the apparatus arranged in the manner outlined, the use of the ordinary house current was permitted since any variation in the strength of the current affecting both circuits simultaneously would be of no consideration. Further, the use of storage or gravity batteries, always of considerable inconvenience, was rendered unnecessary and the constant testing with a control chronometer previously necessitated by the effect of slight variations in the current was eliminated. The apparatus in this form was apparently mechanically perfect and did not permit any considerable latency in any part of the arrangement.

It was, however, desirable to know that the chronoscope was recording perfectly both at the beginning and at the end of the experimental period. For this purpose some reliability measures were made. To test the reliability of the chronoscope the Cattell gravity chronometer was employed. This control instrument was set for an interval of two hundred sigma. The heavy weight held at the top of a two meter column by large magnets, when released started and stopped the recording mechanism of the chronoscope by means of two wheel contacts set at the proper angles. Checking the readings of the chronoscope with the standard interval determined the reliability of the chronoscope. The chronometer has been figured and described

by Cattell[3]. He found it to be very reliable and in a test[4] of three successive series of ten trials each, with a normal time of 100 sigma, readings whose mean variations were 0.54, 0.64, and 0.56 sigma were obtained. The reliability measures for the chronoscope at the beginning of the present investigation were the following:

199.7	M.V. .9
198.8	M.V. 1.8
199.7	M.V. 1.4

Each figure represents the average of ten trials. The standard readings were 200 sigma. Taking the mean of these readings gives as the measure of accuracy the figure 199.7 sigma with an M.V. of 1.1. At the conclusion of the experimentation the chronoscope was again tested in the same manner. The results were:

198.1	M.V. .54
198.5	M.V. .50
198.8	M.V. .48

This gives a mean of 198.4 sigma with a mean variation of .54. The conclusion is that the chronoscope was registering perfectly and that discrepancies could not occur from this source.

2. *Procedure.*

There were essentially three presentations of the sound stimulus, but since the method of presentation was substantially the same in all three it is only necessary to give the fundamental process in detail and note the variations. The normal series of reactions comprised simply the normal reactions of the subject to the sound stimulus without any complicating factors or conditions. The "incentive" series, as they will be designated throughout, comprised those reactions to the sound stimulus after the subject had been informed that the time he took to react would be presented to him before the next succeeding reaction occurred. The time was thus used as an incentive to condition the reactions. The third series, designated as the "punishment" set, involved the following explanation to the subject. "This time you will react as before to the sound stimulus. Use the same movement in releasing the key, only be sure that in holding the key down you have had a finger on each of the two copper plates. You will receive an electric shock only when you do not react quickly enough. That is, if you begin to slow down and take long to react

[3] Catell and Dolley, "On Reaction-times and the Velocity of the Nervous Impulse", Nat. Acad. Sc. Sec. Mem., 7, 397, 1893.

[4] Catell, "Chronoscope and Chronograph", Phil. Stud., 9, 309, 1894.

you will not be able to get away from the key without being shocked. A shock means then that you are not doing as well as you have been doing and that your reaction time is long. Avoid the punishment by speeding up and by maintaining that speed."

The subject, screened off from everything but his reacting key, was placed at one end of the table opposite the experimenter. The experimenter recorded the reading of the chronoscope. As the chronoscope was started a ready signal, simply the word "READY", was given the subject who placed the first two fingers of his right hand upon the knob of the key, pressing it down against its base. The circuit through the electromagnets of the chronoscope was thus closed. After an interval of approximately two seconds, the experimenter closed the control switch which caused the stimulus to be given simultaneously with the closing of the circuit through the upper electromagnets. Completing this latter circuit started the recording mechanism of the chronoscope. The subject, as soon as he perceived the stimulus, released his key thereby breaking the circuit and stopping the recording of the chronoscope. This method of procedure was followed throughout the normal series of reactions.

In the second series of reactions, designated in the statistical tables as the "incentive" set, another step was added to the process used in obtaining the normal reactions. Immediately before giving the signal "Ready", the time of the subject's previous reaction was presented to him by auditory presentation in the form of a statement such as, "Your time was 150 sigma", or later simply as "150", the subject understanding thereby that that was his reaction-time for the trial just completed. Then the signal "Ready", a foreperiod of about two seconds, followed by the sound stimulus to which the reaction was made with the readings recorded as above and the reaction was completed.

With the next series, the punishment set was given, and the procedure became somewhat more complicated for the experimenter. Now the time of the preceding reaction was read and recorded as before, but was not divulged to the subject. The experimenter set the pendulum in place; threw the trip-switch, as shown in the apparatus diagram, into position; gave the ready signal as the chronoscope was started; waited the proper length of time, then gave the stimulus. The pendulum in its swing tripped the switch which opened the punishment circuit through the subject's key. Whether the subject received the shock or not depended solely upon the quickness with which the subject released his key and got away from it. While the time of connecting the punishment circuit with the subject's key

could be varied, the strength of the current was not varied but remained constant throughout the experiment.

3. Standard Conditions.

Standardized conditions, as determined by previous investigators in the field of reaction-time, were adhered to throughout the experiment. It has been determined most recently by Froeberg[5] that the reaction-time increases as the intensity of the stimulus decreases. Consequently the intensity of the sound was kept as constant as possible. Further the nature of the apparatus itself was such that the duration of the stimulus was constant during all periods of work. This factor was of importance, for a variation in the duration of the stimulus has been cited as a cause of varied times of reaction. Referring to Froeberg again, he concludes that the effects of variation of the duration on the reaction-time are "(1) that the time of reaction increases with a decreasing duration of the stimulus, (2) that the time of reaction increases arithmetically as the duration of the stimulus decreases geometrically."

In determining the optimum length of the foreperiod the history of this particular phase of reaction-time was canvassed very thoroughly. The greatest of care was exercised in varying the length of the foreperiod so as to keep it within very narrow limits and yet not have it so regular as to enable the subject to feel the rhythm or to obtain aid in any way in anticipating the stimulus. The constant and close attention of the experimenter was required by this factor in order to avoid this possibility as a source of error. Todd[6] has given a very complete resumé of the findings of the investigations of the foreperiod. He says, "The interval of from one and a half to two seconds has been experimentally determined as the most favorable for obtaining regular reaction-time. Martius found that the reactions with an irregular interval between the signal and reaction stimulus result in a time intermediate between that with a regular signal and with no signal at all. Estel has found that the most favorable interval is two and one-fourth seconds; Wundt places it at two and one-half . . . . . and a recent investigator, Breitweiser, has found that the optimal interval between the signal and stimulus, and the one most often preferred by his subjects was a period of from one to four seconds. Bliss states: 'Experiment has shown that when an interval between warning and stimulus is always the same the mind is soon able to estimate the interval correctly and always reacts just at that

[5] Froeberg, "The Relation between the Magnitude of the Stimulus and the Time of Reaction", Archives of Psych., 8, 1907.

[6] Todd, "Reaction to Multiple Stimuli", Archives of Psych., 25, 1912.

time whether it hears the stimulus or not.' Woodworth: 'If the stimulus follows the signal at an irregular interval, the reaction-time is not so short as when the procedure is regular. If, indeed, the procedure is so regular that the moment of the stimulus can be exactly anticipated, the movement may be made to coincide in time with the stimulus, and the whole character of the experiment be thus changed. This result is avoided by varying the preliminary interval within narrow limits. The most favorable interval between the ready signal and the stimulus is one or two seconds; a shorter time does not allow the subject to prepare himself fully for the stimulus, while a longer period than two seconds allows more time than was needed and so affords a chance for wandering of the attention.' " The more recent tendency seems to be in favor of an interval between the ready signal and the stimulus of from two to four seconds. Supporting this view is the statement from Woodworth and Poffenberger[7] that the investigations have shown that the most favorable interval is usually from two to four seconds, varying somewhat from one individual to another. That is, the reactions were quicker when the interval was of this length than when it was as short as one second or as long as five seconds. The existence of a most favorable interval seems to be established. One second is almost too short a time to enable good preparation, while an interval of over four seconds causes the state of readiness to fluctuate.

Before taking any records in this experiment the subjects were instructed and practiced in the kind of movement to make in releasing the key in response to the stimulus. It was found that all of the subjects felt more comfortable and believed that they could react more quickly and with less variation by simply lifting the fingers from the key instead of drawing away from it. The former involved movement of the fingers and wrist only, whereas the latter caused the whole arm and even a movement of the body to be included. Consequently the subjects were instructed to react by lifting the fingers; to use a sensory type of reaction and to adhere to that mode of response consistently throughout the experiment. Several investigators, Wundt, Titchener, Breitweiser, and others have found that there is an appreciable difference between the two types of reacting. The motor type, it is claimed, has the advantage over the sensory type, but as far as this investigation is concerned this discussion does not pertain since only the one type of reaction was involved and further since comparisons of the several series of reactions was made for each subject and not between subjects.

[7] Woodworth and Poffenberger, "Experimental Psychology" (Mimeog.), 1920, 191.

Chapter III.

THE RESULTS.

The results of the experiment are stated in terms of the improvement caused by the factors of incentive and punishment. The time of the reaction is given in sigma. There are three types of reactions, the normal, the incentive, and the punishment. Each one of these types is in turn divided into three series based upon the order of presentation in the daily set of reactions. The order of presentation was rotated in order to avoid a time error as well as to distribute practice and fatigue effects equally throughout all of the series of reactions. Each figure in these tables of results is the average of 350 single reactions for subjects (N. and J.) and the average of 500 single reactions for subject H. In treating the results two groupings are possible either one of which shows the gain or improvement in the time of a reaction by an incentive or by punishment. The first grouping is determined by the time of presentation at each daily sitting. For instance, the first day's results were obtained in the order, normal first, incentive set second, and punishment set third; the second day's results were in the order, incentive set first, punishment set second, and the normal third. Then the third day's results were in the order, punishment set first, normal second, and incentive set third, and so on through the experiment. The second method of grouping is obtained by taking all the several types of reactions given first throughout the experiment in one group, those given second in another group, and those given third in a final group. Then comparing the three types of reactions within each classification, the amount of improvement is obtained for each position.

The general results of the experiment are given in the following tables. Table I is a summary table of the original measures given completely in another connection later, with the additional data from which the reliability measures are calculated. An inspection of the table will show the surprisingly large saving in the time of the response to the sound stimulus caused by the accompanying factors, incentive and punishment. The conclusion that may be formulated from this table is that the introduction of a positive incentive is a powerful factor in reducing a normal reaction-time, which ordinarily is supposed to be as fast as the subject is able to react. That is, when measuring the

reaction-time of subjects who are coöperating and seriously doing their best, a normal reaction is secured representing their practiced rate of responding to sound. But here the introduction of an incentive reduces the time below this normal and speeds up a regular response already thought to be at its best. The average was found to be six percent of the normal time.

Then introducing a negative incentive, that is, something to be avoided, in this case the electric shock, the previous low normal is reduced fifteen percent. In other words, a positive incentive secures a reduction of 8.8 sigma and a negative incentive 21.4 sigma.

Explanation of Table I: In this table the records of the reactions are given in the three orders in which they were presented to the subjects. Order I corresponds in sequence to those obtained on the first day; Order II to those of the second day, and Order III to those of the third day as explained above. The time is given in sigma. Each figure represents the average of 350 reactions for subjects N. and J. For subject H. the average is based upon 500 reactions. The general or total average of each type of reaction is given at the bottom of each column. The M.V.'s are the average deviations of the reactions grouped by fifties from the average. The P.E.'s are the probable errors of the averages, derived by the formula,

$$\text{P.E.} = \frac{.8453\ \text{M.V.}}{\sqrt{n}}$$

TABLE I.

Normal, Incentive, and Punishment Reaction Series.

ORDER I.

	Normal		Incentive		Punishment	
	Av.	M.V.	Av.	M.V.	Av.	M.V.
N.	144.1	2.8	135.8	2.2	125.4	1.9
		P.E. .89		P.E. .70		P.E. .60
H.	144.1	1.5	134.9	2.0	118.0	1.5
		P.E. .40		P.E. .53		P.E. .40
J.	141.0	4.8	133.6	3.3	123.8	1.6
		P.E. 1.53		1.05		.51

ORDER II.

	Normal		Incentive		Punishment	
	Av.	M.V.	Av.	M.V.	Av.	M.V.
N.	144.5	4.3	136.2	1.8	124.1	2.4
		P.E. 1.37		.57		.76
H.	147.4	4.5	134.8	2.4	119.3	2.1
		P.E. 1.2		.64		.56
J.	141.7	1.8	134.1	2.5	123.6	1.3
		P.E. .57		.79		.41

ORDER III.

	Normal		Incentive		Punishment	
	Av.	M.V.	Av.	M.V.	Av.	M.V.
N.	144.9	4.1	135.8	2.2	125.5	1.9
		P.E. 1.31		.70		.60
H.	146.0	2.2	135.9	2.6	118.6	2.3
		P.E. .59		.69		.61
J.	142.0	3.7	134.7	3.3	123.7	1.9
		P.E. 1.18		1.05		.60
Average	143.9		135.0		122.3	
		P.E. .45		P.E. .20		P.E. .67

From the averages given in the previous table, the amount of improvement both in terms of sigma and in terms of percent has been calculated. Table II gives this improvement for each subject in terms of sigma. The three orders of presentation are given.

TABLE II.

Normal, Incentive, Punishment Order.

		Improvement by Incentive	Improvement by Punishment
(H)			
Normal	144.1		
Incentive	134.9		
Punishment	118.0	9.2	26.1
(N)			
Normal	144.1		
Incentive	135.8		
Punishment	125.4	8.3	18.7
(J)			
Normal	141.0		
Incentive	133.6		
Punishment	123.8	7.4	17.2

Incentive, Punishment, Normal Order.

		Improvement by Incentive	Improvement by Punishment
(H)			
Normal	147.4		
Incentive	134.8		
Punishment	119.3	12.6	28.1
(N)			
Normal	144.5		
Incentive	136.2		
Punishment	124.1	8.3	20.4
(J)			
Normal	141.7		
Incentive	134.1		
Punishment	123.6	7.6	18.1

Punishment, Normal, Incentive Order.

		Improvement by Incentive	Improvement by Punishment
(H)			
Normal	146.0		
Incentive	135.9		
Punishment	118.6	10.1	27.4
(N)			
Normal	144.9		
Incentive	135.8		
Punishment	125.5	9.1	19.4
(J)			
Normal	142.0		
Incentive	134.7		
Punishment	123.7	7.3	18.3

Interpreting the results of the foregoing table in terms of percent of improvement and grouping in the same general way, the figures are as shown in the next table.

TABLE III.

Improvement by Incentive and Punishment in Percent.

When the series was presented in the Normal, Incentive, Punishment order the percent improvement was:

Subject	By Incentive	By Punishment
H.	6.0	18.1
N.	5.7	12.9
J.	5.2	12.1

When the series was presented in the Incentive, Punishment, Normal order the percent improvement was:

Subject	By Incentive	By Punishment
H.	8.5	19.0
N.	5.7	14.1
J.	5.2	12.7

When the series was presented in the Punishment, Normal, Incentive order the percent of improvement was:

Subject	By Incentive	By Punishment
H.	6.9	18.7
N.	6.2	13.3
J.	5.1	12.8

Grouping together the reactions according to the second method of grouping mentioned previously (p. 25), slightly varied percents of improvement are obtained. Whenever the groups were presented first in the daily series the percents were:

Subject	By Incentive	By Punishment
H.	6.1	17.6
N.	5.4	12.9
J.	4.8	12.2

Grouping as above all the sets presented second throughout, the percents were:

Subject	By Incentive	By Punishment
H.	7.6	18.2
N.	6.8	14.3
J.	5.9	12.9

Grouping the sets always presented third in the series, the percents were:

Subject	By Incentive	By Punishment
H.	7.8	19.9
N.	6.0	13.2
J.	4.9	12.6

Figures 2, 3 and 4, are graphic representations of the percent of improvement as given in the first part of Table III (p. 29).

To further summarize the results and show more concisely the influence that incentive and punishment may have upon one's normal reaction-time, the percent of improvement brought about by the conditions of the experiment, for all subjects and under all conditions were grouped together, giving the following:

TABLE IV.

	Percent improvement by Incentive	Percent improvement by Punishment
Order No. 1	5.4	14.2
Order No. 2	6.7	15.1
Order No. 3	6.2	15.2

In this table "Order No. 1", means that all of the three types of conditioning the reaction were presented first in some series throughout the experiment and that all these were grouped together. The other two orders were derived in a similar manner.

Then summarizing the first section of Table III the following results in which "Order N." means that the series were presented in the order Normal, Incentive, and Punishment. "Order I." means that the Incentive set was given first, the Punishment set second, and the Normal set third. "Order P." means that the Punishment set was first, the Normal second, and the Incentive set third. The groupings are as above and obtained in the same manner.

	Percent improvement by Incentive	Percent improvement by Punishment
Order N.	5.6	14.3
Order I.	6.5	15.2
Order P.	6.0	14.9

Up to this point comparisons have been made on the basis of the position of the reaction sets in the series and remarkably large gains have been determined. Another method of showing approximately the same substantial improvement may be applied by basing the comparisons upon the total number of reactions obtained for each subject. These results have been worked out both in terms of sigma and in terms of percent of improvement. Table V gives a comparison in sigma of the amount improved as determined from the total number of reactions of each of the three subjects. For subject H. the reactions total 4500, while for subjects J. and N. the reactions total 3150 each. In this table the comparisons are given for each type regardless of the position in the daily series.

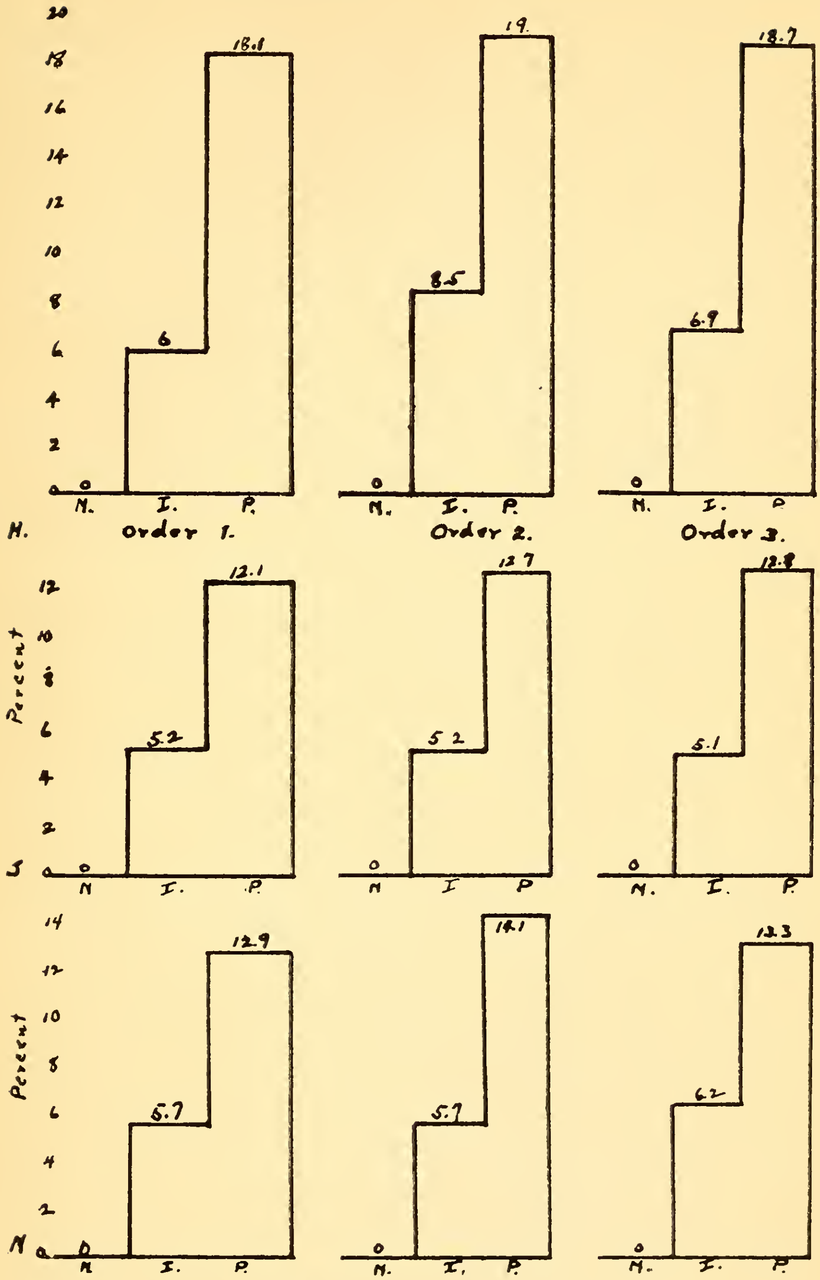

Fig. 2,3,4. Percent Distribution of Improvement.

TABLE V.

		Improvement by Incentive	Improvement by Punishment
Subject H.			
Normal Average	145.83		
Incentive "	135.20		
Punishment "	118.63	10.63	27.20
Subject N.			
Normal Average	144.50		
Incentive "	135.93		
Punishment "	125.00	8.57	19.50
Subject J.			
Normal Average	141.23		
Incentive "	134.13		
Punishment "	123.70	7.10	17.53

Converting these results into percents of improvement, the following is obtained. In this table the total average improvement of all the subjects, regardless of the position in the series in which the conditioning factors were given, may be thus stated.

TABLE VI.

Improvement by Incentive	6.0%
Improvement by Punishment	14.8%
Stating the same in terms of sigma:	
Improvement by Incentive	8.8
Improvement by Punishment	21.4

If practice has a dominant influence upon the time of reaction, then the reactions at the end of the day's work would show correspondingly better time than at the beginning of the work period. Similarly, the reactions at the end of the complete series of reactions would be quicker than those at the beginning. Bearing practice in mind one would expect to find greater improvement when any one type of reaction is in the last position in the series than when it is in any of the preceding positions. That is, the punishment set, for instance, when given last in the series ought to show greater improvement over the normal set than the punishment set does when given first. But what do the figures show? Referring to Table II, in the punishment type the improvement over the normal is 27.4 sigma when the punishment set is given first in the series, but only 26.1 sigma when given last. Likewise punishment in the second or intermediate position substantiates this conclusion. The improvement when given second in the series is 28.1 sigma and 26.1 sigma when given last.

A similar comparison of the amount of improvement may be drawn between the punishment set and the incentive type of reaction with similar results, verifying the premise that practice was entirely eliminated before obtaining any results and that any improvement noted was not due to the influence of practice. A survey of the figures of the other subjects show the same general result. With the amount of improvement as affected by position in the series as the criterion, it may justly be concluded that practice was entirely eliminated. The results, therefore, are determined from reactions obtained at the apparent physiological limit.

Figure 5 is a graphic representation of a typical case showing that practice was entirely eliminated. The three types of reaction proceed each at a distinct level, but parallel to each other. There is no trace of the customary sharp decline apparent in the usual practice curve. Each point on the curve is the average of ten reactions.

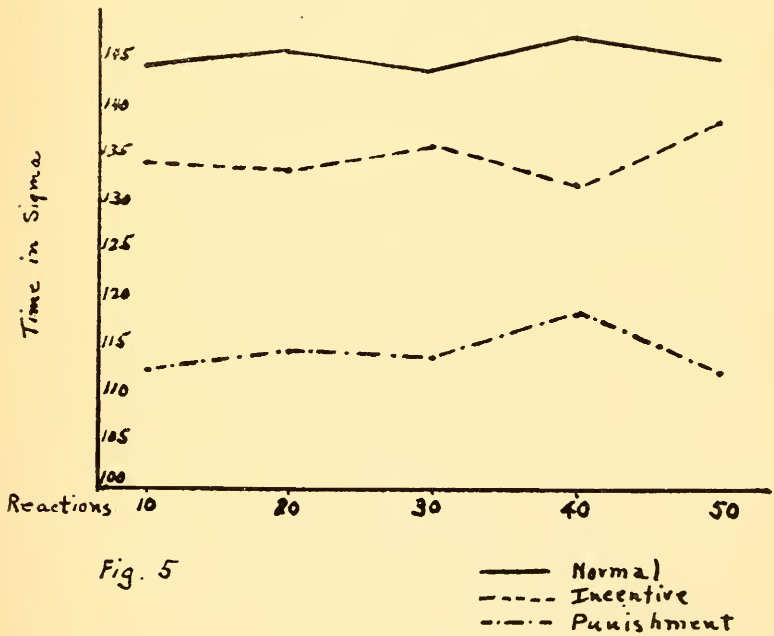

Fig. 5

1. *Interpretation of Results in Terms of Reliability.*

The consideration of the improvement factors of the experiment may be terminated at this point and the attention directed instead to the determination of the reliability of the measures obtained. Thus far the average time has been given and compared with other averages of the various series, but nothing in the way of reliability of these averages has been stated.

Turning to the original measures themselves, as shown in Tables VII, VIII, and IX, it is to be noticed that each figure represents the average of fifty reactions. The mean variations are the average deviations of the fifty single or individual reactions from the average. The mean variations are quite low in most cases, showing that the subjects were well trained and had reached the practice level before any reactions were recorded. It is usual to measure the reliability of an average by the size of the probable error. The P.E.'s in these records are the probable errors of the averages found according to the formula:

$$\text{P.E.} = \frac{.8453 \ \text{M.V.}}{\sqrt{n}}$$

in which the number of cases, "n", equals 50.

In Fig. 6 is shown the distribution of the single reactions of the three types, the normal, the incentive, and the punishment. The reactions were grouped according to the limits within which they fell and for purposes of distribution these groups were of five sigma differences. The total number of single reactions included in each of the curves of the distribution is 3600. The curves show very clearly that the three types of reaction were on distinct levels, though with some overlapping. The median for the normal is 144, for the incentive is 135, and for the punishment is 122. It is also noticeable that in both the normal and the incentive there is more spread than in the punishment set. In the latter the cases are grouped more which gives the curve the higher and narrower shape. The range in this case is 40, whereas it is 60 in the incentive and 65 in the normal.

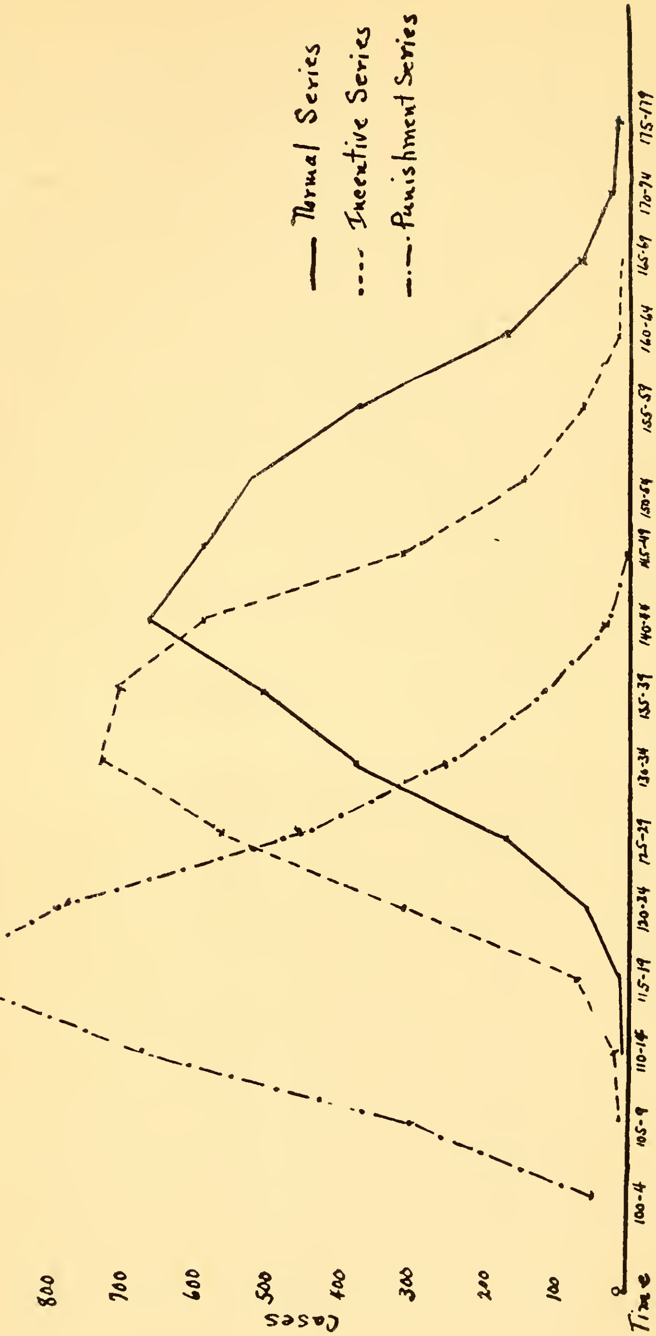

Fig. 6.

Distribution of Single Reactions.

TABLE VII.

Each number in the table is the average time of fifty reactions. The number in a parenthesis designates the position in each daily series of reactions in which the normal, incentive, or punishment set was given. (Subject H.)

Normal			Incentive		Punishment	
(1)	Av.	144.2	(2)	133.0	(3)	120.3
	M.V.	7.5		5.5		7.2
	P.E.	.89		.65		.85
(3)		148.1	(1)	133.0	(2)	121.0
		8.1		6.7		5.2
		.96		.79		.62
(2)		145.6	(3)	131.8	(1)	121.5
		6.8		8.9		6.5
		.81		1.06		.77
(1)		138.1	(2)	132.1	(3)	117.4
		8.3		6.1		4.7
		.99		.72		.56
(3)		152.3	(1)	141.1	(2)	118.3
		7.2		6.1		5.8
		.85		.72		.69
(2)		141.7	(3)	133.4	(1)	113.2
		8.7		8.8		6.6
		1.03		1.05		.78
(1)		144.0	(2)	137.9	(3)	119.2
		8.5		8.5		9.1
		1.01		1.01		1.08
(3)		158.5	(1)	133.4	(2)	123.4
		7.4		7.9		7.8
		.88		9.4		.93
(2)		145.4	(3)	131.9	(1)	114.2
		7.5		5.6		5.7
		.89		.66		.68
(1)		145.0	(2)	134.6	(3)	114.3
		7.8		5.7		4.5
		.93		.68		.53
(3)		153.2	(1)	134.8	(2)	124.3
		7.4		6.2		6.3
		.88		.74		.75
(2)		150.3	(3)	137.6	(1)	118.8
		5.7		8.1		5.8
		.68		.96		.69
(1)		142.7	(2)	133.1	(3)	117.6
		8.7		5.1		5.6
		1.03		.60		.66

Normal		Incentive		Punishment	
(3)	142.4	(1)	130.3	(2)	116.2
	12.3		8.1		5.5
	1.47		.96		.65
(2)	144.0	(3)	138.4	(1)	118.2
	6.0		8.1		6.5
	.71		.96		.77
(1)	144.1	(2)	134.9	(3)	120.7
	6.8		5.4		5.4
	.81		.64		.64
(3)	145.2	(1)	137.0	(2)	115.6
	7.2		7.2		4.4
	.85		.85		.52
(2)	148.0	(3)	136.0	(1)	117.3
	8.2		5.4		4.5
	.97		.64		.53
(1)	145.5	(2)	136.1	(3)	118.7
	6.9		5.4		5.1
	.82		.64		.60
(3)	144.0	(1)	136.3	(2)	118.0
	7.7		6.1		4.4
	.91		.72		.52
(2)	149.7	(3)	141.5	(1)	119.5
	6.8		5.7		5.7
	.81		.68		.68
(1)	145.1	(2)	138.3	(3)	118.0
	6.9		5.7		5.0
	.82		.68		.59
(3)	147.5	(1)	137.4	(2)	118.8
	8.2		6.0		4.5
	.97		.71		.53
(2)	146.9	(3)	139.5	(1)	123.6
	7.8		7.0		5.1
	.93		.83		.60
(1)	145.6	(2)	131.7	(3)	119.1
	5.8		6.0		5.0
	.69		.71		.59
(3)	142.0	(1)	131.1	(2)	119.2
	5.8		5.2		5.0
	.69		.62		.59
(2)	146.2	(3)	134.4	(1)	120.4
	7.0		6.4		5.2
	.83		.76		.62
(1)	147.6	(2)	138.1	(3)	115.0
	6.6		7.7		7.0
	.78		.91		.83
(3)	140.9	(1)	134.4	(2)	118.3
	5.6		6.2		5.3
	.66		.74		.63
(2)	142.3	(3)	135.0	(1)	120.0
	7.0		6.7		4.5
	.83		.79		.53

TABLE VIII.

Each figure in this table is the average of fifty reactions. The number in a parenthesis designates the position in each daily series in which the normal, the incentive, and the punishment set of reactions to the sound stimulus was presented. (Subject N.)

	Normal		Incentive		Punishment
(1) Av.	141.4	(2)	133.3	(3)	123.3
M.V.	6.7		6.7		8.4
P.E.	.79		.79		1.00
(3)	139.0	(1)	135.5	(2)	123.6
	8.1		6.3		6.1
	.96		.75		.72
(2)	137.3	(3)	132.5	(1)	121.9
	6.4		6.0		6.2
	.76		.71		.74
(1)	140.0	(2)	135.5	(3)	126.1
	6.6		7.7		6.4
	.78		.91		.76
(3)	150.0	(1)	140.6	(2)	127.4
	7.0		7.9		6.4
	.83		.94		.76
(2)	144.6	(3)	133.0	(1)	125.1
	6.1		6.8		5.3
	.72		.81		.63
(1)	143.8	(2)	138.2	(3)	130.2
	6.6		6.9		6.0
	.78		.82		.71
(3)	144.3	(1)	137.1	(2)	127.8
	6.6		7.6		6.6
	.78		.90		.78
(2)	145.5	(3)	136.0	(1)	123.0
	7.7		7.0		6.3
	.91		.83		.75
(1)	149.8	(2)	141.4	(3)	126.8
	8.1		7.6		6.4
	.96		.90		.76
(3)	146.3	(1)	137.2	(2)	123.4
	5.7		6.4		6.1
	.68		.76		.72
(2)	151.0	(3)	141.5	(1)	130.8
	6.0		6.9		6.0
	.71		.82		.71
(1)	146.6	(2)	133.6	(3)	124.1
	5.3		6.5		5.1
	.63		.77		.60

Normal		Incentive		Punishment	
(3)	135.4	(1)	131.5	(2)	120.0
	7.8		7.0		6.7
	.93		.83		.74
(2)	139.2	(3)	132.6	(1)	125.4
	6.3		6.6		6.2
	.75		.78		.74
(1)	141.4	(2)	135.3	(3)	123.3
	7.5		7.4		5.0
	.89		.88		.59
(3)	146.9	(1)	136.6	(2)	120.7
	8.2		7.7		5.6
	.97		.91		.66
(2)	148.8	(3)	136.0	(1)	126.0
	6.0		7.6		6.2
	.71		.90		.74
(1)	145.9	(2)	133.7	(3)	124.2
	8.6		8.0		5.9
	1.02		.95		.70
(3)	150.2	(1)	135.5	(2)	125.8
	7.1		5.5		4.6
	.84		.65		.59
(2)	148.4	(3)	130.2	(1)	126.6
	6.4		6.3		6.3
	.76		.75		.75

TABLE IX.

Each number is the average in sigma of fifty reactions. The number in a parenthesis designates the position in each daily series in which the normal, the incentive, and the punishment set of reactions to the sound stimulus was presented. (Subject J.)

Normal		Incentive		Punishment	
(1) Av.	137.3	(2)	133.5	(3)	123.6
M.V.	6.2		7.2		5.9
P.E.	.74		.85		.70
(3)	137.0	(1)	132.3	(2)	124.6
	7.6		6.7		5.2
	.90		.79		.62
(2)	139.0	(3)	131.6	(1)	124.2
	6.9		7.0		6.0
	.82		.83		.71
(1)	140.2	(2)	132.3	(3)	123.6
	9.4		6.0		5.8
	1.12		.71		.69
(3)	143.1	(1)	132.9	(2)	123.1
	8.9		6.1		6.7
	1.06		.72		.79

Normal		Incentive		Punishment	
(2)	136.7	(3)	129.4	(1)	120.0
	6.5		8.6		5.3
	.77		1.02		.63
(1)	139.6	(2)	132.4	(3)	125.2
	7.3		7.2		6.9
	.87		.85		.62
(3)	142.8	(1)	136.9	(2)	123.5
	8.6		7.5		7.0
	1.02		.89		.83
(2)	143.3	(3)	133.4	(1)	121.8
	8.9		6.7		5.4
	1.06		.79		.64
(1)	136.1	(2)	127.6	(3)	118.7
	8.4		6.3		5.5
	1.00		.75		.65
(3)	140.8	(1)	129.7	(2)	120.3
	8.1		7.5		5.3
	.96		.89		.65
(2)	147.0	(3)	135.8	(1)	126.3
	9.3		7.1		6.3
	1.11		.84		.75
(1)	157.0	(2)	145.0	(3)	127.0
	7.2		9.3		7.7
	.85		1.11		.91
(3)	141.1	(1)	132.6	(2)	125.6
	7.8		6.4		5.2
	.93		.76		.62
(2)	138.7	(3)	132.9	(1)	122.8
	9.4		6.2		6.7
	1.12		.74		.79
(1)	142.0	(2)	134.1	(3)	124.0
	8.7		7.6		6.2
	1.03		.90		.82
(3)	141.6	(1)	134.6	(2)	123.1
	7.3		7.5		5.7
	.87		.89		.68
(2)	148.8	(3)	144.9	(1)	123.6
	7.8		6.0		6.9
	.93		.71		.82
(1)	135.2	(2)	130.9	(3)	125.0
	8.3		5.9		6.7
	.99		.70		.79
(3)	146.0	(1)	140.0	(2)	125.5
	6.1		6.9		6.5
	.72		.82		.77
(2)	140.7	(3)	135.3	(1)	127.4
	8.3		8.6		8.0
	.99		1.02		.95

In determining the reliability of the sigma improvement resulting from the conditioning factors of incentive and punishment as noted in the preceding tables, the P.E.'s of the differences were calculated. According to Thorndike[1], "The unreliability of a difference between A and B equals the square root of the sum of the square of the unreliability of A and the square of the unreliability of B." The probable error of the difference was calculated from the formula given in the following "Reliability Table." The M.V.'s used in this process are not the variations of the individual measures from the average, but the variation of the average measure of 350 and 500, according to the subject, reactions from the average of the total group including seven and ten such group averages, depending upon the subject.

Drawing conclusions from the results given in Table X, it can be said that for subject N., the lowest reliability measure gives an actual difference which is 5.5 times the P.E. Interpreting this in terms of probability, there is only one chance in five thousand that the obtained difference may be due to something other than the conditioning factors used in the series. All the other differences for this same subject range entirely beyond any possibility of chance happening.

Subject J.'s differences rank somewhat more within the realm of chance. A P.E. of 1.8 is derived with a difference which is 4.1 times the P.E. But as this is the lowest, it is fair to assume that the difference is real and not invalidated by the possibility of chance.

The results of subject "H" seem entirely beyond any question since the nearest difference is 9.6 times the P.E.

If instead of forming conclusions from the three types of reactions divided into groups according to the position in the series in which each type was presented to the subject, the total number of each kind of reaction serve as the basis for the conclusion somewhat larger probable errors are obtained with a corresponding decrease in the certainty of the differences.

With subject "N" an improvement of 8.5 sigma was developed by incentive, that is, a normal reaction of 144.5 sigma was reduced to 135.9 sigma with a P.E., of the difference of 1.7. This means that the obtained difference was just five times the probable error. Introducing punishment caused a further decrease of 19.5 sigma, or from 144.5 to 125.9 sigma with a P.E. of 1.6. The obtained difference in this case is 12.1 times the P.E.

A normal reaction-time of 141.2 sigma for subject "J" was improved by the incentive 7.1 sigma, bringing the average incentive-

[1] Thorndike, "Mental and Social Measurements", 193.

reaction down to 134.1 sigma. The P.E. of the difference was 1.9, making the actual difference 3.7 times the P.E. This was the lowest probability of any measure in the entire experiment. For the same subject the improvement secured by punishment amounted to 17.5 sigma or from 141.2 to 123.7 sigma, with a P.E. of 1.8 being 9.7 times the P.E. for the difference.

The results of subject H. were reduced from 145.8 to 135.2 sigma by incentive, a difference of 10.6 sigma with a P.E. of 1.5. Here the difference is seven times the probable error. Punishment established the low level in reaction-time in this experiment with this subject. The decrease was from 145.8 to 118.6 sigma, a saving of 27.2 sigma and a P.E. of 1.4. The difference is here 19.4 times the P.E. In the formula used for these results "n" was 21 for the first two subjects and 30 for the last subject.

TABLE X.

Reliability Table.

	Normal	Incentive		Punishment	
(Subject H.)					
Average (1)	144.1	(2)	134.9	(3)	118.0
M.V.	1.5		2.0		1.5
Difference			9.2		26.1
P. E.			.67		.56
Average (3)	147.4	(1)	134.8	(2)	119.3
M.V.	4.5		2.4		2.1
Difference			12.6		28.1
P. E.			1.3		1.3
Average (2)	146.0	(3)	135.9	(1)	118.6
M.V.	2.2		2.6		2.3
Difference			10.1		27.4
P.E.			.91		.84
(Subject N.)					
Average (1)	144.1	(2)	135.8	(3)	125.4
M.V.	2.8		2.2		1.9
Difference			8.3		18.7
P. E.			.74		.65
Average (3)	144.5	(1)	136.2	(2)	124.1
M. V.	4.3		1.8		2.5
Difference			8.3		20.4
P.E.			1.5		1.6
Average (2)	144.9	(3)	135.8	(1)	125.5
M.V.	3.9		2.7		1.9
Difference			9.1		19.4
P. E.			1.5		1.3
(Subject J.)					
Average (1)	141.0	(2)	133.6	(3)	123.8
M.V.	4.8		3.3		1.6
Difference			7.4		17.2
P.E.			1.8		1.6
Average (3)	141.7	(1)	134.1	(2)	123.6
M.V.	1.8		2.5		1.3
Difference			7.6		18.1
P.E.			.70		.90
Average (2)	142.0	(3)	134.7	(1)	123.7
M.V.	3.7		3.3		1.9
Difference			7.3		18.3
P.E.			1.2		1.6

In the foregoing table is given the average results for each subject in each series when presented in the three orders. For two of the subjects, N. and J., the average is derived from 350 reactions, while for the third subject H., the average is obtained from 500 reactions. This gives measures in groups numbering 7, 7, and 10, respectively

for the subjects. The M.V. is based on these group deviations from the average. The difference column in the table denotes the actual amount of improvement in sigma due to the conditioning factors in the several types. The difference is in all cases between the normal and incentive in the first column, and between the normal and punishment in the last column. The P.E. of the difference is derived from the formula,

$$\text{P.E.} = \sqrt{\frac{(.8453\ \text{M.V.})^2\text{A.}}{\sqrt{\text{n}}} + \frac{(.8453\ \text{M.V.})^2\text{B.}}{\sqrt{\text{n}}}}$$

in which "n" is 7 or 10 depending upon the subject.

The number in the parenthesis designates the position in the series in which each type of reaction condition was used, i.e. (1) means that the normal reaction set was taken first, (2) second, and so on.

An interesting point may be worked out in connection with the punishment series of reactions by noting the effect of a shock upon the immediately following reactions. Averaging all the reactions which are recorded just prior to the infliction of a shock, the result is for each of the three subjects 125.5 sigma, 122.2 sigma, and 124.3 sigma respectively. The average of the reaction for which the shock was received was 138.6, 140.3, 140.6 sigma respectively. Taking the average of the first reaction following the shocked reaction the figures are 121.4, 113.2, 123.2 sigma; for the second reaction following the results are, 120.6, 115.1, 120.4. In the case of the first subject it is to be noted that the first reaction immediately following the shock is slightly longer than the second one following. The third subject's results show the same thing. It would seem then for these two subjects that the full benefit of the shock, or rather the full effect of it is not apparent immediately, but is attained in the second reaction following the shock. The reactions recorded third after the punishment average 120.7, 118.3, and 120.2 sigma. From then on there is a gradual slowing up until the next reaction receiving a shock speeds the process again. Then this process of reduction is repeated and holds for a time. Judging from this particular case it would seem that the reactions for which a shock is given become slower as the series advances, i.e., the last shocked reaction is longer than the first one. But this is not the general case. The length of the shock reactions vary throughout the set. There does not appear to be an undue slowing as a reaction following a shock. On the contrary, while there is a slowing it is very gradual and is about the same as the slowing appearing in the reactions taken before any shock is given.

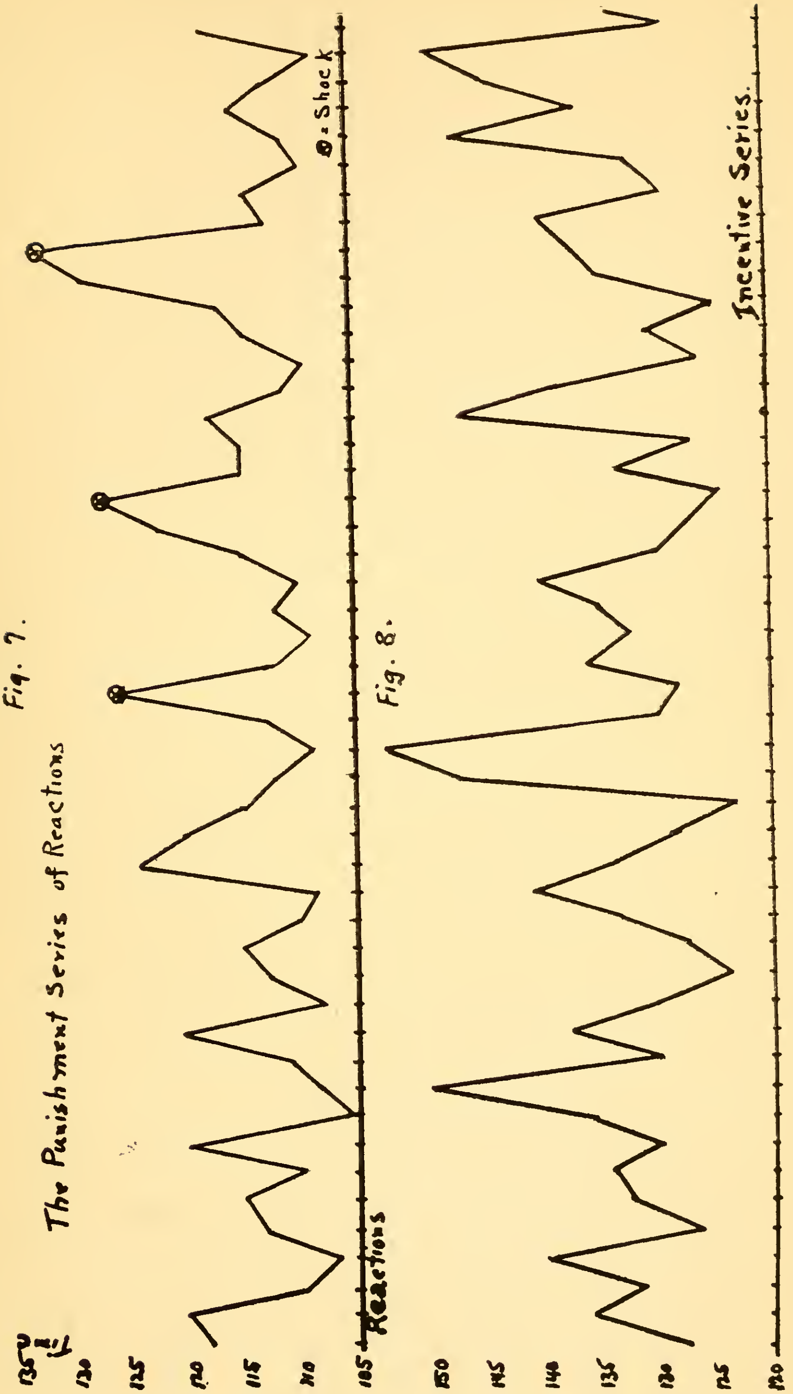
Fig. 7.
The Punishment Series of Reactions
= Shock
Reactions
Fig. 8.
Incentive Series.

The graph in Fig. 7 is a typical case showing the effect of the shock. It was selected at random from all the results and is a fair sampling of a group. The graph also shows that while the shock reduces the time of a reaction very rapidly, the speeding up effect of the punishment does not hold very long. A punishment series taken one day creates a low level in the subject's reacting for that day, but this low level does not hold over to the next day. The reduction is not permanent. In the same way the duration of the effect of a slow reaction in the incentive series is very brief. Summarizing the data given and putting it in tabular form we have:

Subject.	Last before Shock	Shock	1st fol. Shock	2nd fol. Shock	3rd fol. Shock
J.	125.5	138.6	121.4	120.6	120.7
H.	122.2	140.3	113.2	115.1	118.3
N.	124.3	140.6	123.2	120.4	120.2

A similar procedure was followed with regard to the incentive series. The first point to be answered was this. Does an exceedingly slow reaction tend to discourage or inhibit the subject so that the following reactions are slower, or does it give him a greater drive and stimulate him to speed up and make quicker reactions? The records worked over as above in the punishment series give these results. The average of the reactions immediately preceding a very slow reaction is for each subject, 135.3 sigma, 139.7 sigma, and 137 sigma. Then averaging the reactions considered as slow the result is, 149.3 sigma, 156.4 sigma, and 155 sigma respectively. The first following reaction averages 133.1, 137.4, and 132.8 sigma. The second following reaction averages 132.1, 132.2, and 134.8 sigma. The third reaction following averages 134.2 sigma, 135.3 sigma, and 136.3 sigma.

Here again the conclusion may be formulated that the incentive that the reaction was slow acts as a facilitation in the same manner as the shock does. The maximum effect is not immediate, but rather delayed, since the second following reaction is shorter than the first following. However, this is not conclusively established as the third subject's results show that the full facilitation effect is reached immediately. There is then in general a stimulation brought about by the incentive that the reaction was slow, but with variation in the time within which the incentive attains its maximum strength. Fig. 8 is a graphic representation of the incentive series showing the rapid decrease after a slow reaction. The high points are the very slow reactions and in each case it will be noticed that the next succeeding re-

actions continue for a time on a new low level. The second high point in the graph shows how the full effect of the slow reaction was not attained until the second reaction following. Grouping the figures in order to make comparison the easier we have:

Subject	Last before Incentive	Slow Reaction	1st fol.	2nd fol.	3rd fol.
N.	135.3	149.3	133.1	132.1	134.2
J.	139.7	156.4	137.4	132.2	135.3
H.	137.0	155.0	132.8	134.8	136.3

A second consideration of the incentive series was whether or not the improvement noted was really due to the incentive. Might not the improvement only be the result of the conversation involved in stating the time to the subject? A few words, of course, but possibly they were enough to keep the subject awake and more attentive than in the normal series where no word was spoken. If that were true then the improvement ought to be the same throughout the series and not vary according as the reaction was slow or fast. The previous paragraph has shown that the reactions following a very slow reaction are very rapid and Fig. 8 shows that there are varying degrees of improvement depending upon the length of the incentive reaction immediately preceding. Since then such differences appear within the series, the improvement must be caused by the motive set up by the incentive and not by the conversation.

The effect of the fast reaction in the incentive series was a slight slowing up of the reaction. The average of the reactions taken just before the fast reactions was 123 sigma, the fast reaction averaged 119 sigma and the average of the reactions immediately following was 132 sigma. Another subject averaged 135 sigma, 120 sigma, and 137 sigma respectively. The third subject gave results in which the average of those before and after a fast reaction were equal, i.e., 130, 119, 130.

Treating the middle range of the incentive series in the same way the results show that reactions which were intermediate between the very fast and the very slow reactions had an alternating facilitating and inhibitory effect. Sometimes the immediately following reactions were slower than the preceding intermediate reactions and again they were faster. It is, therefore, impossible to formulate any more definite conclusion for the intermediate reactions. However, since the effects did vary according as the reactions were fast or slow in this incentive series, it can be said that the incentive used was a real motive affecting the results and not simply conversation.

A comparable effect may be attributed to premature reactions. They do not affect the three types of reactions in the same way for the incentive set shows that the after-effect of a premature reaction is towards an increase in the time of the next reaction rather than to decrease it. But in the other two series, the normal and the punishment, the effect of the premature reaction is to reduce the time of the following responses. On the whole, the premature reactions indicate a facilitating effect similar to the effects of the slow reactions in the incentive set and the punished reactions. The figures for the premature reactions in the three types, normal, incentive, and punishment, are the following:

	Reaction before	Premature	Reaction following
	151.5	67	145.5
Normal	147.0	69	141.1
	152.5	79	144.7
	144.2	82	145.5
Incentive	131.4	66	135.5
	140.0	65	115.5
	134.5	67	132.1
Punishment	117.5	70	115.5
	134.3	75	123.0

These results are the averages of all the premature reactions occurring in the various sets. The subjects are in the order J., H., and N. in each case.

Should the criticism be made that the improvement caused by the incentive and by the punishment might be due to the presence of premature reactions in the results rather than to the influence of the conditioning factors of the experiment, the defence can be made by an appeal to the distribution curve given in Fig. 6. These three curves of the distribution of the single reactions approximate in shape the normal bell-shaped curve. Assuming for a moment that premature reactions are included in the distribution, then the lower end of each curve would tend to weight the mean in proportion to the number of premature reactions included. It has been stated previously that premature reactions were made in the ratio of 1 : 3 : 6, in the normal, the incentive and the punishment series respectively. Then, of course, that is the cause of the improvement noted as being due to the incentive and the punishment factors. But, continuing the assumption, what happens if the lower part of each curve is cut off? By such an operation, the premature reactions would be excluded and if they had been the cause of the lowering of

the time in each series, then the remaining portion of each curve ought to be about at the same level. Obviously this does not happen. Even when the lower portion of the curve is cut off the remaining cases for each type of reaction group themselves on distinct levels with practically no overlapping. That is, the normal has a mode of 140, the incentive a mode of 130, and the punishment series a mode of 110. Furthermore, the punishment curve shows by its abrupt ending at the lower extreme that premature reactions were not included. Had they been present the curve would have trailed off more gradually and not ceased sharply. It shows also that the reaction-time of the punished reaction was very close to the physiological limit.

The evidence is strongly against assigning the improvement as caused by the premature reactions and the validity of the assumption that the incentive and the punishment are the factors reducing the reaction-time is unshaken.

Chapter IV.

CONCLUSION.

James[1] states, "The reaction whose time is measured is, in short, a reflex action pure and simple, and not a psychic act. . . . The preparation of the attention and volition; the expectation of the signal and the readiness of the hand to move, the instant it shall come; the nervous tension in which the subject waits, are all conditions of the formation in him for the time being of a new path or arc of reflex discharge. The tract from the sense-organ which receives the stimulus, into the motor center which discharges the reaction, is already tingling with premonitory innervation, is raised to such a pitch of heightened irritability by the expectant attention, that the signal is instantaneously sufficient to cause the overflow." In another place James continues, "Expectant attention is but the subjective name for what objectively is a partial stimulation of a certain pathway, the pathway from the 'center' for the signal to that of the discharge. . . . The signal is but the spark from without which touches off a train already laid. The performance, under these conditions, exactly resembles any reflex action. The only difference is that whilst, in the ordinarily so-called reflex acts, the reflex arc is a permanent result of organic growth, it is here a transient result of previous cerebral conditions."

This state was evident in this experiment in varying degrees under the several types of reaction conditions. Consequently premature reactions were sometimes made. The number that were made in each kind of reaction series may be regarded as an index of the degree of expectant attention in that series. From the total number of reactions obtained the ratio of premature reactions was found to be, 1 : 3 : 6, respectively for the normal, the incentive, and the punishment type.

On this point of attention Wundt[2] writes: "When we wait with strained attention for a stimulus, it will often happen that instead of registering the stimulus, we react upon some entirely different impression—and this not through confounding the one with the other. On the contrary, we are perfectly well aware at the moment of making the movement that we respond to the

[1] James, "Principles of Psychology", I., 90ff., 1890.

[2] Wundt, "Physiol. Psych.", 2nd, ed. II., 226.

wrong stimulus. . . . We cannot well explain these results otherwise than by assuming that the strain of the attention towards the impression we expect coexists with a preparatory innervation of the motor center for the reaction, which innervation the slightest shock then suffices to turn into an actual discharge. This shock may be given by any chance impression, even by one to which we never intended to respond. When the preparatory innervation has once reached this pitch of intensity, the time that intervenes between the stimulus and the contraction of the muscles which react, may become vanishingly small." To again quote from James[3], "Usually, when the impression is fully anticipated, attention prepares the motor centres so completely for both stimulus and reaction that the only time lost is that of the physiological conduction downwards. But even this interval may disappear, i. e., the stimulus and reaction may become objectively contemporaneous; or more remarkable still, the reaction may be discharged before the stimulus has actually occurred." In a footnote he gives an explanatory statement of the unusualness of such an occurrence.

With this background we may attempt an explanation of the effects observed in this experiment. One of the possible ones, and to the writer, the most probable is that a state of much keener attention, produced by an incentive and by the expectant punishment, motivates reactions very much prompter than those normally obtained under quieter and more restful conditions. The fact that there is a motive present stimulating the subject to react works the same in reaction-time as it does in all other types of responses to stimuli. How far this improvement may be carried on and to what limits the time of a reaction may be reduced is difficult of determination. The results show that the average time of the punishment series is about as fast as the individual is able to react and it seems the fear of punishment acts as a very powerful facilitator.

That a state of keener attention or concentration of the attention was involved is attested to not only by the premature reactions, but also by the feeling of the subjects. Especially during the punishment set did the subjects evidence the usual signs of close attention as well as copious perspiration and nervous tension. This fact is brought out in an introspective report of one of the subjects. "Introspections in connection with the punishment reaction. A continued feeling of tenseness through-

[3] Op. cit. I., 429.

out entire period of reaction while batteries were connected with key. At first, and at times during the fifty reactions, there was a certain shyness in the hand in approaching the key. This was especially noticeable after a shock had been received. When reacting it was impossible to inhibit impulse of withdrawing violently the whole hand, and the period of pressure on key was always accompanied by much instability or restlessness which often resulted in false or premature reactions. As the experiment progressed a feeling of intense warmth was present. All the above was in contrast to a more or less sleepy calmness in the preceding experiments without electric punishment."

GENERAL SUMMARY

1. Expectant attention reduced the reaction-time in the incentive and punishment series.
2. The factors of positive and negative incentive caused the state of keener attention to be maintained.
3. The limits of reduction depend upon the subject's training and upon the type of the individual, as the only limitation is the physiological time.
4. The actual saving, though not permanent, by incentive is six percent and by punishment is fifteen percent of the normal time. In terms of sigma the amounts saved are eight and twenty sigma respectively.

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